

WHAT IS CLAIMED IS:

1. An optical device comprising:
a transparent material layer having a desired
5 curved surface configuration;
a layer including a variable refractive index
material having a dielectric constant anisotropy and
having a property in which a sign of a difference $\Delta\epsilon$
in dielectric constant due to the anisotropy is
10 reversed at driving frequencies f_1 and f_2 ;
at least two transparent electrodes arranged to
sandwich said transparent material layer and said
layer including said variable refractive index
material; and
15 a driving device supplying a voltage including
said driving frequencies f_1 and f_2 between said
transparent electrodes.
2. An optical device as set forth in claim 1,
20 wherein said driving device sequentially applies
voltages V_1 to V_N having primary frequencies f_1 to
 f_N ($N \geq 2$) to said transparent electrodes for a
predetermined period of time and at a predetermined
interval.

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3. An optical device as set forth in claim 2,
wherein when sequentially applying voltages V_1 to V_N
having primary frequencies f_1 to f_N ($N \geq 2$) to said
transparent electrodes for a predetermined period of
5 time and at a predetermined interval, said driving
device temporarily suspends the supply of the
voltage at a desired phase of said interval and
subsequently resume the supply of the voltage.
- 10 4. An optical device as set forth in claim 1,
wherein a dual-frequency liquid crystal is employed
as said variable refractive index material having
the refractive index anisotropy and the dielectric
constant anisotropy and having a difference $\Delta\epsilon$ of the
15 different dielectric constant which is reversed at
the driving frequencies f_1 and f_2 .
5. An optical device as set forth in claim 4,
wherein a material having a low wettability with the
20 liquid crystal is arranged at least one of positions
contacting said layer of the liquid crystal.
6. An optical device as set forth in claim 4,
wherein an alignment layer for aligning the liquid
25 crystal in one direction is provided at the surface
of said transparent electrode on the side of the

layer including the variable refractive index material.

7. An optical device as set forth in claim 6,
5 wherein a light is incident to a surface of said layer including the variable refractive index material having a more uniform alignment.

8. An optical device comprising a plurality of
10 optical devices defined in claim 6, said plurality of optical devices being arranged in series so that the ordering directions of the respective alignment layers are perpendicular to each other.

15 9. An optical device as set forth in claim 1, wherein said two transparent electrodes are substantially parallel transparent electrodes.

10. An optical device as set forth in claim 1,
20 wherein the surface configuration of the transparent material layer on the side of said layer of the variable refractive index material is a convex lens, a concave lens, a fresnel lens, a prism array, a lens array, a lenticular lens or a diffraction
25 grating, or a curved surface formed by a combination thereof.

11. An optical device as set forth in claim 1,
wherein one of said transparent electrodes is
replaced with an electrode reflecting at least a
part of a light incident to said one of said
5 transparent electrodes.

12. An optical device comprising:
a layer including a variable refractive index
material having dielectric constant anisotropy and
10 having a property to reverse signs of a difference
of dielectric constant $\Delta\epsilon$ due to anisotropy at
driving frequencies f_1 and f_2 ;
at least two transparent electrodes arranged to
sandwich said layer including said variable
15 refractive index material; and
a driving device applying a voltage, in which
voltages from V_1 to V_N respectively having
respective primary frequencies f_1 to f_N ($N \geq 2$) are
superimposed, between said transparent electrodes.

20 13. An optical device as set forth in claim 12,
wherein a transparent material layer having desired
curved surface configuration is disposed between
said at least two transparent electrodes and
25 adjacent said layer including said variable
refractive index material.

14. An optical device as set forth in claim 13,
wherein one of said transparent electrodes is
replaced with an electrode reflecting at least a
part of a light incident to said one of said
5 transparent electrodes.

15. An optical device as set forth in claim 12,
wherein when applying a voltage in which voltages V_1
to V_N having respective primary frequencies f_1 to f_N
10 ($N \geq 2$) are superimposed, said driving device
temporarily suspends the supply of the voltage at a
desired timing and subsequently resume the supply of
the voltage.

15 16. An optical device as set forth in claim 12,
wherein a dual-frequency liquid crystal is employed
as said variable refractive index material having
the refractive index anisotropy and the dielectric
constant anisotropy and having a difference $\Delta\epsilon$ of the
20 different dielectric constant which is reversed at
the driving frequencies f_1 and f_2 .

17. An optical device as set forth in claim 16,
wherein a material having a low wettability with the
25 liquid crystal is arranged at least one of positions
contacting said layer of the liquid crystal.

18. An optical device as set forth in claim 16,
wherein an alignment layer for aligning the liquid
crystal in one direction is provided on the surface
5 of said transparent electrode on the side of the
layer including the variable refractive index
material.

19. An optical device as set forth in claim 18,
10 wherein a light is incident to a surface of said
layer including the variable refractive index
material having a more uniform alignment.

20. An optical device comprising a plurality of
15 optical devices defined in claim 18, said plurality
of optical devices being arranged in series so that
the ordering directions of the respective alignment
layers are perpendicular to each other.

20 21. An optical device as set forth in claim 12,
wherein said two transparent electrodes are
substantially parallel transparent electrodes.

22. An optical device as set forth in claim 12,
25 wherein the surface configuration of the transparent
material layer on the side of said layer of the

variable refractive index material is a convex lens,
a concave lens, a fresnel lens, a prism array, a
lens array, a lenticular lens or a diffraction
grating, or a curved surface formed by a combination
5 thereof.

23. An optical device comprising:

a layer of transparent material having a desired
curved surface configuration;

10 a layer including a variable refractive index
material having a positive or negative dielectric
constant anisotropy;

at least two transparent electrodes arranged to
sandwich said layer of the transparent material and
15 said layer including the variable refractive index
material; and

a driving device for always supplying a voltage
substantially equal to or greater than an amplitude
of a voltage establishing static and vertical
20 alignment in said variable refractive index
material.

24. An optical device as set forth in claim 23,
whercin said voltage from said driving device is an
25 AC voltage having a primary frequency in a range of
1 Hz to 100 Hz.

25. An optical device as set forth in claim 23,
wherein said variable refractive index material is
nematic liquid crystal.

5 26. An optical device as set forth in claim 23,
wherein said at least two transparent electrodes are
substantially in parallel.

27. An optical device as set forth in claim 23,
10 wherein the surface configuration of the transparent
material layer on the side of said layer of the
variable refractive index material is a convex lens,
a concave lens, a fresnel lens, a prism array, a
lens array, a lenticular lens or a diffraction
15 grating, or a curved surface formed by a combination
thereof.

28. An optical device as set forth in claim 23,
wherein an alignment layer for aligning the liquid
20 crystal in one direction is provided on the surface
of said transparent electrode on the side of the
layer including the variable refractive index
material.

25 29. An optical device comprising a plurality of
optical devices defined in claim 28, said plurality

of optical devices being arranged in series so that the ordering directions of the respective alignment layers are perpendicular to each other.

5 30. An optical device as set forth in claim 23, wherein a light is incident to a surface of said layer including the variable refractive index material having a more uniform alignment.

10 31. An optical device as set forth in claim 23, wherein one of said transparent electrodes is replaced with an electrode reflecting at least a part of a light incident to said one of said transparent electrodes.

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32. A three-dimensional display device for forming three dimensional image from two-dimensional image on a display portion, comprising:

20 a layer of a transparent material having a desired curved surface configuration;

a layer of a variable refractive index material having a refractive index varying in accordance with a voltage applied thereto;

25 at least two transparent electrodes arranged to sandwich said layer of the transparent material and

said layer including the variable refractive index material;

an imaging position shifting portion for shifting an imaging position of said two-dimensional image displayed on said display portion;

5 a synchronizing portion for synchronizing an updating period of the two dimensional image displayed on said display portion with a shifting period of the imaging point of said imaging position shifting portion; and

10 a driving portion for driving said imaging point shifting portion by applying a voltage to said at least two transparent electrodes in accordance with an output from said synchronizing portion.

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33. A three-dimensional display device as set forth in claim 32, wherein said variable refractive index material of said imaging point shifting portion is liquid crystal.

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34. A three-dimensional display device as set forth in claim 33, wherein a material having a low wettability with the liquid crystal is arranged at least one of positions contacting said layer of the liquid crystal of said imaging point shifting portion.

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35. A three-dimensional display device comprising a plurality of optical devices defined in claim 34, said plurality of optical devices being arranged in series so that the ordering directions of the
5 respective alignment layers are perpendicular to each other.

36. A three-dimensional display device as set forth in claim 33, wherein an alignment layer for aligning
10 the liquid crystal in one direction is provided on the surface of said transparent electrode on the side of the layer including the variable refractive index material of said imaging point shifting portion.

15 37. A three-dimensional display device as set forth in claim 36, wherein a light is incident to a surface of said layer including the variable refractive index material having a more uniform
20 alignment.

38. A three-dimensional display device as set forth in claim 32, wherein said two transparent electrodes are substantially in parallel.

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39. A three-dimensional display device as set forth in claim 32, wherein said display portion displays depth sampling images formed by decomposing a three-dimensional image into two-dimensional images
5 between planes set at a predetermined interval in a depth direction of an image pick-up position, or depicts a line drawing.

40. A driving method of driving a three-dimensional
10 display device including a display portion for displaying two-dimensional images, an imaging point shifting portion disposed between said display portion and an observer, a synchronizing portion for synchronizing an updating period of the two-
15 dimensional images displayed on said display portion with a shifting period of the imaging point of said imaging point shifting portion, and a driving portion for driving said imaging point shifting portion, said a driving method comprising the steps
20 of:

outputting a plurality of driving signals of an output voltage V_N ($N \geq 2$) having frequency f_N as a primary frequency for a predetermined period of time assigned to each of the driving signals in a
25 predetermined sequence to drive said imaging point shifting portion in said driving portion; and

updating and displaying said two-dimensional images in a predetermined sequence on said display portion in said synchronizing portion.

- 5 41. A driving method of driving a three-dimensional display device including a display portion for displaying two-dimensional images, an imaging point shifting portion disposed between said display portion and an observer, a synchronizing portion for
10 synchronizing an updating period of the two-dimensional images displayed on said display portion with a shifting period of the imaging point of said imaging point shifting portion, and a driving portion for driving said imaging point shifting
15 portion, said a driving method comprising the steps of:

in said driving portion:

- generating a driving signal of a predetermined output voltage in which a frequency Ω ($N \geq 2$) is
20 superimposed;

applying said driving signal to said imaging position shifting portion;

- varying said output voltage in a predetermined sequence in accordance with a synchronization signal
25 of said synchronizing portion; and
in said synchronization portion:

outputting a synchronization signal in said synchronization portion when updating two-dimensional images to be displayed on said display portion.

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42. A driving method as set forth in claim 40, further comprising a step of stopping said driving signal for driving said imaging point shifting portion driving a predetermined time duration.

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43. A driving method as set forth in claim 41, further comprising a step of stopping said driving signal for driving said imaging point shifting portion driving a predetermined time duration.

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44. A three-dimensional display device comprising:
a phantom three-dimensional display device for displaying a phantom three-dimensional image; and
a shutter device formed by a shutter element for
controlling a light transmittance, said shutter
device being located at a position where said
phantom three-dimensional image is reproduced or a
position optically equivalent to said position.

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25 45. A three-dimensional display device as set forth in claim 44, wherein said shutter element is two-

dimensionally divided, and each of divided regions are driven independently of the other.

46. A three-dimensional display device as set forth
5 in claim 44, wherein said shutter element lowers a light transmittance in the region of depth sampling images as two-dimensional images of said phantom image at said shutter element position during a time duration that said phantom three-dimensional image
10 is being reproduced on the other side of said shutter element as viewed from the observer.

47. A three-dimensional display device as set forth in claim 44, wherein the material of said shutter
15 element is one or combination of guest-host type liquid crystal containing diachronic dye having a different light beam absorption depending upon an orientation of molecules and liquid crystal having dielectric constant anisotropy, polymer dispersion
20 type liquid crystal containing droplet-like liquid crystal in polymer, polymer dispersed liquid crystal containing a polymer network in liquid crystal, a holographic polymer dispersed liquid crystal having a layer structure of polymer dispersed liquid
25 crystal containing droplet like liquid crystal in polymer and polymer, a holographic polymer dispersed

liquid crystal having a layer structure of said
polymer dispersed liquid crystal containing a
polymer network in the liquid crystal and polymer,
and a polymer dispersed liquid crystal wherein said
5 liquid crystal in said polymer dispersed liquid
crystal is said guest-host type liquid crystal.

48. A three-dimensional display device as set forth
in claim 44, wherein said phantom three-dimensional
10 display device is constructed with a two-dimensional
image display device and a varifocal optical device.

49. A three-dimensional display device comprising:
a phantom three-dimensional display device for
15 displaying a phantom three-dimensional image; and
a shutter device formed by a shutter element for
controlling a light transmittance,

said phantom three-dimensional image being a
real image, and said shutter element being a
20 photoreactive element for lowering a light
transmittance in a real image region at the position
of said shutter element in accordance with an
imaging light beam of said real image.

25 50. A three-dimensional display device as set forth
in claim 49, wherein a material of said

photoreactive element is one of a photochromic material, a material consisting of a material causing a photostructural change and liquid crystal, and a material having a nematic-anisotropic phase transition temperature to be varied by photostructural change.

51. A three-dimensional display device as set forth in claim 49, wherein said phantom three-dimensional display device includes a two-dimensional image display device and a varifocal optical device.

52. A head-mount display device comprising:
two display devices corresponding to left and right eyes and each including a two-dimensional display device and an optical device having a variable focal length; and

a control device for controlling said two dimensional display device and said optical device having a variable focal length,

said display devices being mounted to left and right eyes, and said control device synchronously driving said two-dimensional display device and said optical device to perform three-dimensional display.

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53. A head-mount display device as set forth in claim 52, wherein said optical device further comprises a deflection device for varying a direction of a light incident to said optical
5 device, and said control device controls said optical device in such a way that when the image is moving closer to the eyes according to a change of the focal length, the overall display image of said two-dimensional display device is deflected to be
10 closer toward the center between the left and right eyes.

54. A head-mount display device as set forth in claim 52, wherein said optical device has a
15 transparent material of one of forms of a fixed focus lens shape, a fixed prism shape, and a shape where the fixed deflection mechanism is incorporated into the fixed focus lens or a combination thereof, a layer including a variable refractive index
20 material, and at least a pair of transparent electrodes for sandwiching said layer.

55. A head-mount display device as set forth in claim 54, wherein said variable refractive index
25 material is liquid crystal having dielectric constant anisotropy and refractive index anisotropy.

56. A head-mount display device as set forth in claim 55, wherein said variable refractive index material is liquid crystal having dielectric constant anisotropy and refractive index anisotropy, and being dual-frequency liquid crystal having a different physical property having a different sign of a difference in a dielectric constant corresponding to orientation of the liquid crystal molecules between different frequencies f_1 and f_2 .

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57. A head-mount display device as set forth in claim 54, wherein said variable refractive index material is polymer dispersed liquid crystal, and the droplet size of the liquid crystal or the droplet size of the polymer is smaller than a wavelength of visible light.

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58. A head-mount display device as set forth in claim 54, wherein said fixed focus lens is spherical or non-spherical single lens or fresnel lens.

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59. A head-mount display device as set forth in claim 54, wherein said fixed prism is simple prism or a multi-prism having an array of a plurality of fine prisms.

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60. A head-mount display device as set forth in claim 54, the form where said fixed deflection mechanism is incorporated in to said fixed focus lens is in the form of increasing or decreasing an angle formed by a spherical or non-spherical simple lens or a fresnel lens and an optical axis.

61. A head-mount display device as set forth in claim 52, wherein said driving device sequentially applies voltages V_1 to V_N having primary frequencies f_1 to f_N ($N \geq 2$) to said transparent electrodes for a predetermined period of time and at a predetermined interval.